Summary

The Big Elk fire was directly adjacent to the Button Rock Preserve and burned 4,413 acres of grassland, ponderosa pine, and mixed conifer forest in 10 days costing $4.2 million before restoration. In 2002, 502,000 acres of Colorado forests burned, low fuel moisture and high fuel continuity contributed to this record fire season. Ponderosa pine restoration is needed to return forests to an ecologically sustainable condition and to reduce the hazard of catastrophic fires and insect epidemics.

The City of Longmont seeks to preserve the biological integrity and watershed function of the Button Rock Preserve through the implementation of a Forest Stewardship Plan. Of special concern are the risk of catastrophic wildfire, forest insect and disease infestations, and the spread of noxious weeds. Management also requested that plant and animal species lists are prepared.

Blue Mountain Environmental Consulting met these objectives through the implementation of field sampling efforts, database searches, literature reviews, employment of Geographic Information Systems techniques, and spatial modeling. The condition of forests and rangelands were assessed with the Forest Health Monitoring plot, which evaluates overstory and understory condition. Samples were stratified on the basis of aspect with 5 replicates in southern, eastern/western, and northern forests. Overstory analysis include forest composition, density, and structure. Understory analysis evaluates the composition and abundance of grasses, forbs, and shrubs. Additional inventory efforts focused on the distribution and composition of noxious weeds within the Button Rock Preserve. Known corridors of weed migration including roads, trails, disturbed sites, and riparian corridors were sampled.

Forest density was found to range between 120 and 125 Ft^2/Ac on southern and northern slopes respectively. Composition was similar to that of historical forests. A list of understory species is provided and tabulated according to origin and abundance. Twenty-four separate weed populations were mapped during the field effort. Noxious species encountered include: cheatgrass, dalmation toadflax, white top, curly doc, Canada thistle, musk thistle, bouncing bet, and diffuse knapweed. Field data are summarized and supplemented with information from database searches and have been integrated with Geographic Information Systems. An extensive list of wildlife, including Threatened and Endangered species, is also provided. Wildfire hazards were modeled with BEHAVE. Mitigation measures were then incorporated into forest prescriptions and treatment areas were prioritized in accordance with hazard ratings.

Restoration measures for Front Range ponderosa pine forests include: the creation of clearings ranging in size from 1 - 20 hectares, major reductions in tree density (especially in small diameter classes) resulting in canopy covers of 10 - 30% over most of the landscape, retention of trees greater than 200 years old, removal of most Douglas-fir (except on northern aspects where it should be thinned), and the re-introduction of fire to reduce ingrowth, maintain low forest density and thin Douglas-fir. These goals are reflected in the management prescriptions that have been made for 22 separate management compartments. Species specific management prescriptions are included for all noxious weeds found on the property; a treatment schedual for all operations is included. This document also contains supplementary information necessary for project implementation including: performance standards for forestry operations, forest insect and disease descriptions, extensive weed management discussions, reference literature, and sources of additional assistance.

Introduction

The Button Rock Preserve is a reservoir watershed that is located in the St. Vrain River Valley, seven miles west of Lyons, Colorado, on Highway 66. This walk-in preserve contains the Longmont and Ralph Price Reservoirs along the North St. Vrain Creek. The watershed is managed by the City of Longmont to provide storage for the City's Water Utility, preserve natural resources, and provide outdoor recreation opportunities. The park creates a unique experience for visitors to view wildlife, hike, fish, and rock climb. The Button Rock Watershed dates back to the early 1900's when Longmont first built Longmont Dam on the North St. Vrain Creek. The City acquired most of the now approximately 1200-hectare watershed in the early 1960's from private landowners. Ponderosa pine trees dominate the forest community of Button Rock, except on northern slopes where Douglas-fir and Rocky Mountain juniper become more abundant.

BUTTON ROCK PRESERVE MANAGEMENT HISTORY

Historical accounts reflect that the accessible forested areas were logged for construction timbers from 1880 to 1930 and the rangelands saw cattle grazing until the early 1970's. Evidence of past forest fires can be found throughout the watershed. During the late 1970's until 1985 a mountain pine beetle epidemic threatened trees primarily in the central and western reaches of the City lands. The resulting standing dead trees were cut and removed for firewood. Also during this
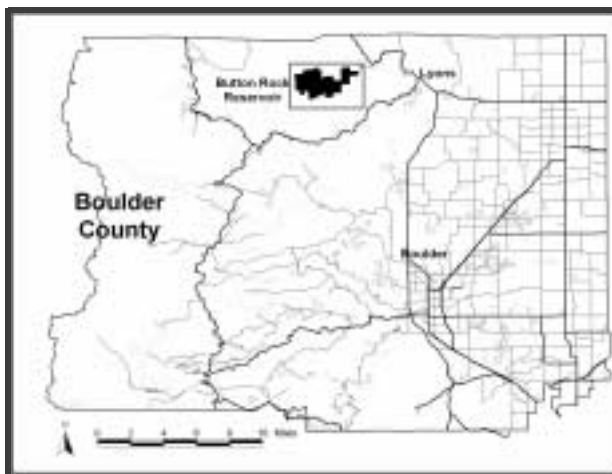
time, several areas of dwarf mistletoe were identified and continue to slowly creep amongst the trees in these same locales. Additionally, Douglas-fir Bark Beetle is evident in several areas, but is not spreading rapidly. From 1987 until present, standing dead trees in accessible areas have been cut down and stacked. Starting in 1999 and continuing each summer through 2002, small diameter ponderosa pine thickets have been thinned along the main entry roadway, totaling approximately 8 hectares of forest. Severe drought in 2002 appears to have increased ponderosa pine mortality by at least four times the annual rate observed since 1987.

Noxious weed control prior to 1987 appears to have been minimal and no known historical documentation is available. Noxious weed infestations on the watershed property include musk and Canadian thistle, dalmatian toadflax, bouncing bet (phlox), spotted and diffuse knapweed, and burdock. The majority of the infestations are in the revegetated areas and adjacent to the roadways. Yearly control efforts since 1987 have consisted of mechanical cutting, hand pulling, and biological control of musk thistle with weevils.

Increased tree mortality due to insect and disease infestations, excessive small diameter regeneration, the risk of wildfire, and the desire to maintain a healthy forest and rangeland have prompted the preparation of this Forest Stewardship Plan.

GOALS AND OBJECTIVES OF THE FOREST STEWARDSHIP PLAN

The City of Longmont seeks to preserve the biological integrity and watershed function of the Button Rock Preserve through the implementation of a Forest Stewardship Plan. Of primary concern are the needs to reduce the risks of catastrophic wildfires, and noxious weed invasion. Forest insect and disease epidemics also need to be addressed. Forest management prescriptions need to preserve and protect the habitat of wildlife species. These goals may be achieved through the implementation of the following project components:

1. Resource mapping: Geographic Information Systems (GIS) mapping will include timber resources, noxious weed infestations, wildfire hazard information, and management unit boundaries.

2. Resource inventory: A descriptive analysis of the existing timber resources including an estimation of timber density is required. An inventory of known noxious weed infestations and any new infestations discovered during site visits will be documented. An inventory of understory species is also required to identify indigenous plants. An inventory of indigenous wildlife species will be prepared including threatened and endangered species probabilities. A general description of soils, and climate will be included.

3. Delineation of individual management units: The watershed land areas will be sectioned into management units based on slope, aspect, accessibility and other factors that will facilitate management prescription for the individual units.

4. Management prescriptions for individual units: Resource management prescriptions are required for the individual units. The prescriptions are needed in order to improve forest and rangeland health as it relates to timber resources, taking into account: stand density, wildfire hazard mitigation, and forest insect and disease infestations. Management recommendations will also include wildlife habitat protection, watershed and facility preservation, and noxious weed control measures.

5. Treatment schedule: A treatment schedule is required to outline the phasing of various management tasks and to guide restoration efforts over the duration of the Stewardship Plan.

ECOSYSTEM MANAGEMENT

Ecosystem management is the most recent evolution in the management of natural resources. This management paradigm is similar to the Multiple Use Sustained Yield initiative, but takes greater steps to preserve the viability of ecological, social, and economic systems. This ecological approach to management blends the needs of people with environmental values in a way that promotes diverse, healthy, productive, and sustainable ecosystems (Christensen et al. 1996, Jensen et al. 1996, Jensen and Everett 1994). Achieving these goals will require that ecological conditions be incorporated into decision processes so that human needs are considered in relation to the sustainable capacity of the system (Kaufmann et al. 1994). A fundamental component of ecosystem management is knowledge of ecosystem conditions, natural disturbance patterns and process, and the productive capabilities of a landscape (Bourgeron and Jensen 1994, Grumbine 1997, Meyer and Swank 1996, Reichman and Pulliam 1996, Salwasser and Pfister 1993, Slocomb 1993).

Ecologically based management of ponderosa pine (*Pinus ponderosa* Laws.) ecosystems within the Colorado Front Range also requires knowledge of ecosystem structure and function prior to significant human alteration that began in the mid to late 1800's. A system's historical range of variability provides a window for understanding the conditions and processes that sustained ecosystems prior to significant human alteration (Swanson et al. 1994). These *reference conditions* serve as a guide for establishing future goals that will protect ecological systems and meet societal objectives (Kaufmann et al. 1994, Kaufmann et al. 1998, Landres et al. 1999, Moore et al. 1999, Morgan et al. 1994). Reference conditions need to be contrasted with current ecological conditions to assess where changes have occurred and to identify negative consequences of system alteration. Together, reference conditions and current conditions are used to identify desired future conditions that are ecologically sustainable, and to guide restoration treatments. A further discussion of relevant information regarding ponderosa pine forests is provided below to detail the reference conditions that will be used to guide restoration efforts at Button Rock.

PONDEROSA PINE FORESTS

A brief comparison of southwestern ponderosa pine forests and Front Range ponderosa pine forests

Historical fire behavior in southwestern ponderosa pine forests was dominated by low-intensity surface fires that maintained an open forest structure and a grassy understory (Covington and Moore 1994). Low intensity surface fires that recurred every 2 to 20 years were typical in presettlement ponderosa pine ecosystems of southwestern areas. In contrast, a mixed severity fire behavior pattern, having both a stand replacing component, and a surface fire component, dominated ponderosa pine forests in the Colorado Front Range (Brown et al. 1999, Kaufmann et al. 2001).

Post settlement changes that have occurred in both areas

Historically fires regulated tree density, species composition, reduced the amount of dead biomass, maintained clearings, and promoted nutrient cycling (Covington and Moore 1992, 1994, Covington and Sackett 1984, Covington and Sackett 1988, Fulé et al. 1997, Mast 1993, Swetnam and Betancour 1990). Fire suppression and cattle grazing, brought by Euro-American settlement in the late 1800's, has caused major

changes in the spatial pattern and ecological process of ponderosa pine ecosystems. These changes have increased tree density and reduced the frequency of natural fires (Covington 1994, Weaver 1961). As a result, trees are colonizing clearings normally maintained by fire and new clearings are not being created. Open savannas with high herbaceous production changed into dense forests with closed canopies and reduced nutrient cycling rates (Covington and Moore 1992, Covington and Sackett 1988, Fulé et al. 1997, Swetnam and Betancourt 1990). Grazing contributed to increased tree densities by reducing herbaceous cover and breaking fuel continuity on the forest floor. Tree seedlings proliferated in the absence of fire and competition from grasses (Harrington and Sackett 1992). Thick organic layers on the forest floor and dense pine canopies also suppress herbaceous vegetation in the understory (Sackett et al. 1993). Increased pine density decreased individual tree vigor resulting in greater mortality from insects, disease and drought. In the absence of fires, surface fuel loads and vertical fuel continuity increased to unprecedented levels creating ideal conditions for crown fires (Covington and Moore 1992, Covington and Sackett 1988, Fulé et al. 1997, Swetnam and Betancourt 1990). Current ponderosa pine forests have large fuel loads, are prone to insect outbreaks, and are more susceptible to large catastrophic fires (Covington 1994, Covington and Moore 1992, Kaufmann et al. 1998, Rapport et al. 1998).

Front Range ponderosa pine forests

Ponderosa pine forests in the central Rocky Mountains have a mixed severity fire pattern. This fire pattern is similar to the moderate-severity fire regime described by Agee (1998) and the mixed and variable fire regime described by Brown (1995). Brown et al. (1999) constructed a fire history near Cheesman Lake; fire scar records and inferences from forest stand ages were used to reconstruct the fire frequency, fire severity, seasonality, and spatial extent of fires during the last 800 years. These fire histories record greater variability in fire interval and intensity than was common in southern areas. This mixed-severity fire regime had fire intervals ranging from 1 to 100 years and high intensity crown fires were more common (Brown et al. 1999) than in southern areas. Research conducted by Goldblum and Veblen (1992) and Laven et al. (1980) also identified a longer mean fire interval in the central Rocky Mountains than in other areas. Shorter growing seasons, poorer soils and erratic summer rainfall in the central Rocky Mountains make the overstory and understory of these forests

less productive. The longer fire intervals and limited fine fuel conditions have created different effects on forest structure in these landscapes than where fire intervals were short (Kaufmann 2000a).

Veblen and Lorenz (1991) used repeat photography to assess changes in vegetation structure and composition of the Colorado Front Range during the last 50 to 100 years. Comparisons of photos of the same landscape taken many years apart revealed an increase in forest fires caused by settlement activities in the 1920's. Subsequent fire suppression resulted in an increase in ponderosa pine stand density, loss of natural clearings and an increase in Douglas-fir (*Pseudotsuga menziesii*). Fornwalt et al. (2002) used the Forest Vegetation Simulator to predict historical forest density and diameter distributions. While it is difficult to make definitive prediction of these parameters and equate these findings to other areas of varying productivity, it is clear that tree densities have increased substantially over the last 100 years.

FIGURE 1. (Top) Previous view of the Cheesman Lake landscape, which contains clearings that contribute to landscape heterogeneity. (Bottom) Current landscape in the South Platte Basin with no clearings illustrates landscape homogeneity.

Historically, ponderosa pine forests were a mosaic of forested areas and clearings (Peet 1988), unlike the homogenous forests common today (Figure 1). Hadley and Veblen (1993) suggested human disturbances and fire suppression have resulted in increased landscape homogeneity and decreased mean stand ages. It is hypothesized by Kaufmann (personal communication) that homogenous ponderosa pine forests are more vulnerable to catastrophic fire than heterogeneous forests with clearings. Large scale stand replacing fires can result in

erosion, sedimentation, and flooding that threatens human health (Bruggink et al. 1998).

LANDSCAPE DIVERSITY AND DISTURBANCE

Disturbance effects landscape diversity by creating different successional stages within a landscape. In a study of seedling recruitment and fire history in the Cheesman landscape, Kaufmann et al. (2000b) determined that many patches of trees were uneven aged with a distinct age cap, suggesting that seedling establishment occurs in pulses following stand replacing fires. Both surface and localized crown fires maintained a complex and dynamic landscape of low density forest parches and transient openings from less than 1 to more than 100 hectares (Brown et al. 1999, Kaufmann et al. 2001). These openings contained shrubs and herbs typically associated with forest habitats, but lacked a tree canopy, apparently because of fire caused mortality followed by very slow reforestation (Kaufmann et al. 2003). Fire disturbance and variable timing of tree recruitment into openings was determined to be the primary influence effecting spatial heterogeneity.

Aspect was implicated as an important regulator of tree distribution in the Colorado Front Range by Mast et al. (1997). Tree invasion into grasslands and tree densities were greater on northern slopes while southern slopes remained non-forested in many areas. These differences were attributed to droughty conditions on southern slopes. These results are supported by Tobler (2000) who investigated the cause of landscape patterns in the South Platte Basin. Clearings within the Cheesman Lake study area were believed to be transient features of the landscape because most areas contained coarse woody debris indicating a previous forested condition. Additionally, there were no significant differences between the soils of forested areas and clearings. It was concluded that vegetative mosaics in ponderosa pine forests of the Colorado Front Range result primarily from stand replacing fires and subsequent difficulty of tree recruitment on harsh southern slopes. Ponderosa pine restoration is needed in many places in the western U.S. to return forests to an ecologically sustainable condition and reduce the hazard of catastrophic crown fires and insect epidemics (Kaufmann et al. 2003, in press).

PONDEROSA PINE RESTORATION

Restoration goals aimed toward ecological sustainability depend upon historical fire behavior and tree recruitment patterns. Restoration plans must also incorporate factors effecting landscape diversity. Findings reported by Kaufmann and Hessel, 2000, Kaufmann et al. 2001, Kaufmann et al. 2003, Kaufmann et al. 2000a on ponderosa pine forests having a historically mixed severity fire regime suggest several specific restoration goals for forests in the Colorado Front Range and South Platte Basin.

1. Openings ranging in size from 1 to 20 hectares should be created, amounting to 15-25% of the landscape. Openings should be interspersed with patches of low density forest and managed to last decades.

2. Major reductions in tree density are needed, especially in smaller diameter classes, resulting in canopy covers of 10-30% over most of the landscape. Forest density should be reduced through a combination of mechanical thinning and prescribed fire.

3. Most Douglas fir should be removed, except on northern aspects where they should be thinned.

4. Old trees (200 years or older) should be retained because they provide an important component of the historical age structure. Trees 300-500 years old were common in ecological reference areas.

5. Fire should be re-introduced to minimize ingrowth of new trees, maintain low forest density and thin out Douglas-fir.

There are many benefits associated with the restoration of Front Range ponderosa pine forests including reducing the risk of catastrophic wildfires while improving the likelihood of ecological sustainability (Kaufmann et al. 2000a). Forest thinning and re-introducing landscape heterogeneity are suitable treatments meeting several objectives (Kaufmann et al. 2003). Restoration efforts can reduce the risk that wildfires pose to the safety of people living at the wildland/urban interface and the costly impact fires have on reservoir systems. Reduced forest densities would also benefit the Pawnee montane skipper (a threatened species requiring forest clearings) and other species that favor an open forest condition. Alleviating stress and competition between trees by reducing forest density will increase trees' resistance to insect epidemics. Fire mitigation promotes sustainable ponderosa pine ecosystems by restoring them to a historical condition (Kaufmann 2003, personal communication).

Additional data about historical forest density and patch species composition are presented in Figure 2. This model reflects historical conditions of ponderosa pine forests that occurred in the South Platte Basin, but is also appropriate for other portions of the Front Range having similar fire regimes and relatively coarse textured soils. The percentages should be considered as central tendencies, recognizing there is temporal and spatial variation around these values (Kaufmann et al. 2003). The original model presented by Kaufmann also contained age distribution data that indicated approximately 35% of the researched forest contained trees that were older than 200 years. The model was simplified to contain only canopy cover estimates for the Button Rock Forest Stewardship Plan because definitive age distribution data were not collected and management prescriptions based on this information will exceed the scope of this restoration plan. It is known however, that all trees older than 200 years need to be preserved.
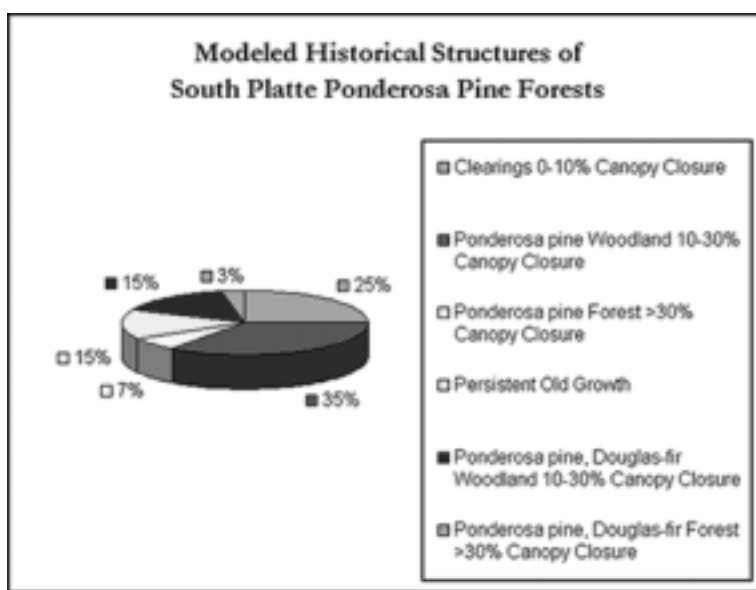
FIGURE 2. Modeled Historical Structures of South Platte Forests. This chart indicates that a large component of the historical landscape was a low density woodland or clearing. Additionally, mixed Douglas-fir forest were a relatively small portion of the landscape (Kaufmann et al. 2003).

FOREST INSECTS AND DISEASES

Several insects and diseases attack Front Range forests including dwarf mistletoe, mountain pine beetle, western spruce budworm, and the Douglas-fir beetle. These vectors can spread quickly in overly dense, stagnated, or drought stressed forests. The ecological value of the land is diminished and left prone to wildfire. Treatment options do exist for infected trees, but the most effective defense against insects and disease damage involve alleviating stress and competition between trees prior to attack (Paige et al. 2002).

NOXIOUS WEEDS

Noxious weeds are a "biological wildfire" capable of drastically effecting plant and animal diversity, impoverishing native plant populations, damaging watersheds, and lowering site productivity. However, unlike the temporary effects of wildfire, the ecological damage of weed invasions is long lived and often worsen over time. Invasive plants impact agricultural lands, rangelands, and forests, alter ecosystem function, and threaten native biodiversity important for economic, ecological, and ethical reasons (Vitousek et al. 1997; Mack et al. 2000). In fact, invasive species cost the United States approximately $137 billion annually in the form of lost revenue and environmental damage (Pimentel et al. 2000). Nearly half of the nations' threatened and endangered species are listed due to competition with, or predation by, non-native species (Pimentel et al. 2000).

In the Front Range of Colorado, there are a host of weeds that seriously impact native plant communities, thereby reducing the wildlife values in those communities. Cheatgrass (*Bromus tectorum*), has displaced large areas of native grasslands in the Button Rock Preserve. Other weeds, such as musk thistle (*Carduus nutans*), Canada thistle (*Cirsium arvense*), and diffuse knapweed (*Acosta diffusa*), are also threatening revegetated areas and riparian corridors at Button Rock. Many of the weeds at Button Rock, such as *Alyssum parviflorum* (an annual mustard), and other annual forbs are not a management concern, but the noxious weeds are. Noxious weeds are invasive plants introduced to native ecosystems that are capable of displacing native vegetation while turning a productive ecosystem into a monoculture of weeds (CWMA 2002). Noxious weed lists are maintained by federal, state, or local management agencies that mandate plant management.

CHAPTER 2 **Methods**

The Button Rock Forest Stewardship Plan was developed with cost-efficient field sampling methods integrated with literature reviews, database searches, geographic information systems analyses, and spatial modeling. In this way, costs were minimized while dependable site information was obtained. We employed Forest Health Monitoring plots to assess overstory and understory condition; these efforts were combined with purposeful weed sampling. Protocols here presented are grouped in accordance with sample design. Data from all analyses are subsequently re-combined and presented in the Results Chapter.

SITE DESCRIPTION

Climate of the Boulder area is of the semiarid, continental type. The mean annual air temperature from measurements made at the Longmont weather station is 48.1°F, mean annual summer temperature is 68.4°F. Precipitation at the Longmont station is 12.0 inches per year, but increases to 18 inches in the foothills (USDA Forest Service 1975). Forests at Button Rock are typical of xeric (arid), open ponderosa pine, Douglas-fir forests of the lower montane zone of the Front Range (Peet 1981). Ponderosa pine is the dominant overstory species and typically forms pure stands on south facing slopes. Understories are sparsely populated with grasses, herbs and shrubs. Northern slopes support denser stands of ponderosa pine and mix with Douglas-fir trees. Solis at Button Rock are coarse textured and derived from decomposed granite. Additional soil information and mapping units are not currently available; the Arapaho Roosevelt National Forest is currently preparing the soil survey.

SAMPLE DESIGN

Aerial photographs were reviewed prior to field sampling to identify vegetative associations and to guide the distribution of plots. Previous vegetative studies in the montane ponderosa pine zone have indicated that species composition and forest density are strongly correlated with aspect; furthermore, there is little difference in the vegetative composition of eastern and western slopes. The effects of elevation and slope were considered to be negligible within the project area; we therefore stratified samples on the basis of aspect. Samples were grouped to include southern forests, eastern/western forests, and northern forests with five samples in each class for a total of 15 FHM plots. Sample sites were located on slopes within 20° of the primary aspect of the sampling unit and at least 100 meters away from roads or trails. Slopes greater than 40° were not sampled and rock outcrops were avoided. Because financial constraints prohibited a large sampling effort with a randomized design, sample sites were located in areas that were determined to be ecologically representative, thus requiring fewer total samples.

GEOGRAPHIC INFORMATION SYSTEMS ANALYSIS

GIS mapping and analyses for the project were completed in ArcView version 3.3 and included two primary data types: aerial photographs and digital GIS maps. Data utilized for the analysis described below were obtained form the Boulder County website. The GIS procedures for the project included the following components:

1. Information gathering: Aerial photographs, GIS layers - Digital Elevation Model (DEM), vegetation, digital quadrangle map, and boundary map is gathered and integrated into the report.

2. Vegetative type mapping: Current digital vegetation maps are scrutinized and updated with aerial photographs and ground observations.

3. Stand delineation: Management compartments are delineated on the basis of landform and forest cover type. Results of the BEHAVE simulation were used to prioritize treatment areas.

4. Noxious weed mapping: A map of weed distribution was obtained from Boulder County and subsequently updated with information from the watershed manager and field observations.

5. Information display: Integrated field data are displayed on maps within this project document.

6. Spatial modeling: GIS techniques were also used to prepare map coverages that were used in fire behavior modeling and analysis of forest density.

UNDERSTORY ASSESSMENT

Vegetative composition and abundance were evaluated with the Forest Health Monitoring (FHM) Plot, (Figure 3) as modified by Stolgren 2002 (personal
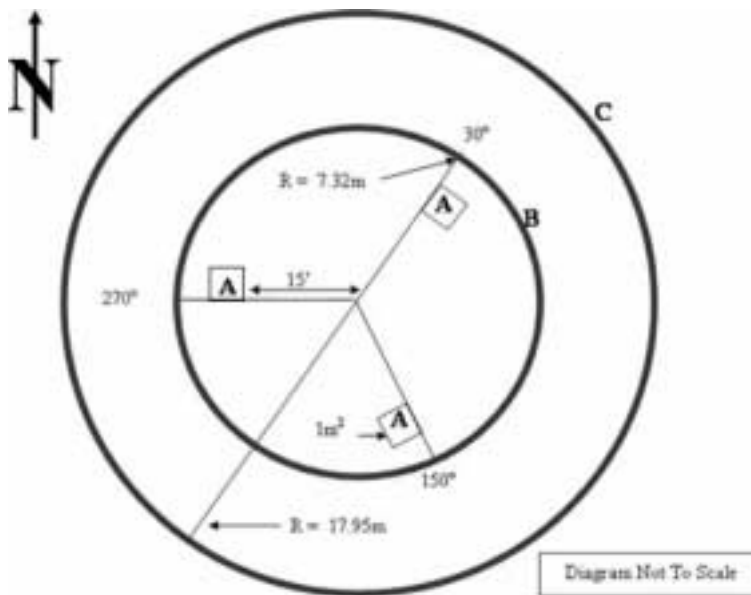
FIGURE 3. Modified Forest Health Monitoring Plot..

Data Collection		
A Plot	B Plot	C Plot
• Frequency of understory species	• Understory species present	• UTM coordinate
• Percent cover by understory	• Tree species greater than 3.9" DBH	• Slope, aspect, elevation
• species	• Tree species less than <3.9" DBH	• Plot photo
• Percent cover by cryptobiotic soil crusts and moss	• Number of trees	• Tree species greater than 40" DBH
• Percent cover by abiotic factors (rock, soil, duff, scat, wood, water)	• Tree diameter	• Diameter of trees greater than
	• Basal area	• 40" DBH
	• Incidence of tree insect and diseases	

communication). The FHM Plot is a subset of a larger sampling protocol used by the Federal Government to assess multiple aspects of forest condition throughout the United States. The FHM plot size is designed to be the same size as the minimum mapping resolution of satellite images. The FHM Plot utilizes a multi-scale design with three $1m^2$ subplots that are nested within a $168m^2$ circle. The frequency and percent cover of species present, and the percent cover by ground variables (soil, rock, duff, wood, water, moss, cryptobiotic soil crust) were made in the $1m^2$ subplots. A search for additional species was conducted in the $168m^2$ circle.

Additional plants encountered on the project site, but outside the sample plots, were also recorded to provide a more comprehensive species list. These plants are not included in the frequency and percent cover estimations, they only appear in the master species list and are distinguished from plants that were encountered within the FHM sample plots. Understory data analysis was conducted in BioPlot, a Microsoft Access 2000 program designed by Rick Shory of the Natural Resource Ecology Laboratory at Colorado State University. Nomenclature corresponds to Weber (2002) and the Natural Resource Conservation Service PLANTS website.

OVERSTORY ASSESSMENT

Overstory characteristics including tree species, trees per acre, basal area, tree diameter, and incidence of disease were evaluated at the same location. Sapling regeneration was evaluated by counting all trees less than 10 centimeters diameter at breast height (DBH) that occurred within the $168m^2$ circular plot. The plot basal area was obtained by tabulating the diameter of all trees greater than 10 centimeters DBH that occurred in the B plot. A search for trees larger than 101.6 centimeters (40 inches) DBH was conducted in a larger $1012m^2$ circle that was centered at the same location. A photograph was taken at each plot center, primary slope and aspect were measured with a magnetic compass, a Universal Transverse Mercator (UTM) coordinate and elevation were obtained with a Garmin global positioning system receiver. Overstory data were analyzed in Microsoft Excel spreadsheets.

NOXIOUS WEED ASSESSMENT

The richness, abundance and location of noxious weeds were assessed in four ways. 1) A search for existing weed maps was conducted in databases hosted by Boulder County and the Colorado Natural Heritage Program. A base map was obtained from the Boulder County database, additional weed populations were added to it. 2) Additional weed infestations were indicated by Dennis Fisher of the Button Rock Preserve and used to update our Geographic Information Systems (GIS) database. These infestations were visited in the field to document their location, size, identity, and percent in accordance with North American Invasive Plant Mapping Standards. 3) Additional mapping efforts focused on known corridors of weed migration. All roads and trails were surveyed as well as disturbed areas and some key riparian corridors. Forests and clearings were also surveyed as the study team traversed between FHM plots. 4) Data from the FHM plots were used to estimate the percent cover and composition of weeds on the landscape scale within the project site. These data were then integrated into the GIS database to generate a weed map.

WILDLIFE ASSESSMENT

Natural Resource Services, Inc. (NRSI) was contracted to review existing wildlife inventory data relating to the Button Rock Preserve and to generate a list of wildlife species. Species listed were determined by reviewing ranges published in various technical and popular publications (Robbins et al. 1966, Peterson 1990, Page and Burr 1991, Stebbins 1985, Burt and Grossenheider 1976, Lechleitner 1969, Armstrong 1972) as well as interviews with personnel associated with the U.S. Fish and Wildlife Service (Peter Page 2003), the Colorado Department of Wildlife (per. comm. Gary Skiba 2003), the Colorado Natural Heritage Program (per. comm. Michael Menefee 2003), the Boulder County Parks and Open Space Department (per. comm. Rick Koopman 2003), and the Button Rock Preserve (per. comm. Dennis Fisher 2003). Probability of occurrence within Button Rock Preserve was determined for each species after a review of range and habitat data provided in the literature. The common name, scientific name, probability of occurrence, seasonality of occurrence and habitat preference are provided in the appendices.

A literature review of special status (Threatened and Endangered) species for the Button Rock area was also conducted. These data were developed from the Colorado Department of Wildlife Species of Concern List (revised April 2003) as well as from consultation with the above agencies. Findings are presented in a similar format as above. NRSI also reviewed the Forest Stewardship Plan and management prescriptions prepared by the lead contractor to provide comments and suggestions regarding wildlife management and habitat preservation.

WILDFIRE ASSESSMENT

Anchor Point Group, Inc. was contracted to provide technical support for wildfire mitigation. Anchor Point ran a BEHAVE simulation to compute potential fire behavior characteristics over the entire landscape for constant weather and moisture conditions.

The Wildfire Hazard classification represents a relative ranking of locations based upon expected surface fire intensity. The surface fire intensity is dependant upon fuel type, slope, aspect, and elevation (Figure 4). The USDA Forest Service's fire behavior model, BEHAVE, was used to determine hazard levels that are based upon a Fire Behavior Index derived from custom calculations. BEHAVE is a nationally recognized methodology for estimating a fire's intensity and rate of spread given topograph, fuels and weather conditions. Anchor Point uses FlamMap developed by Systems for Environmental Management, Missoula, MT and the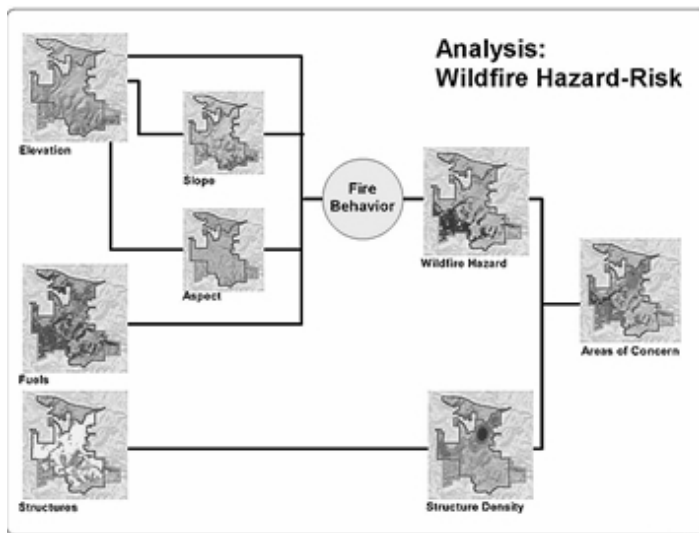 Fire Sciences Laboratory of the Rocky Mountain Research Station (USDA Forest Service, Missoula, Montana) to evaluate the potential fire conditions in the study area. Button Rock

FIGURE 4. BEHAVE Model Inputs and Outputs.

Reservoir encompasses approximately 3000 acres that are broken down into 100 meter grids. Using FlamMap's spatial analysis capabilities, each 10m sq grid is queried for its slope, aspect and fuel type. These values are input in to a BEHAVE model run using reference weather information. The outputs to the model include the estimated Rate of Spread (ROS) and Flame Length (FL), Fireline Intensity (FI) and Heat per Unit Area (HPUA) for a fire in that $10m^2$ grid. The model computes these values for each grid cell in the study area. These values are then reclassified into Wildfire Hazard classes of None, Low, Moderate, High, and Very High.

CHAPTER 3 **Results**

Field data have been summarized and integrated with information from spatial analysis to describe current conditions at Button Rock. These findings are compared with historical conditions where appropriate, and subsequently used to create management prescriptions (Management Prescriptions Chapter) to satisfy project objectives.

GEOGRAPHIC INFORMATION SYSTEMS ANALYSIS

Results of the GIS analysis are presented primarily as project map coverages. Map 1 indicates the location of roads, trails and sample sites. The location of weed populations and forest insect and disease infestations are presented on Map 2. This map should be used in conjunction with the noxious weed table (Appendix 8) to monitor weed populations and evaluate the efficacy of management actions. Management compartments are delineated on Map 3. Compartments have logical boundaries so that they will be easy to locate on the ground; they are separated by roads, streams, trails, ridgelines, or by a break in aspect. These areas were also designated on the basis of consistent forest composition and density. Twenty two management compartments were delineated in 6 different zones, compartments range in size between 23 and 279 acres. Map 4 presents the same management compartments with the addition of contour lines; areas having slopes steeper than 30 degrees have been shaded to indicate where forest operations will be suspended due to erosion potential. Map 5 presents the results of the BEHAVE simulation run by Anchor Point superimposed on top of the management compartments. Areas with the reddest colors indicate the highest probability of fire, and are therefore the greatest treatment priority.

UNDERSTORY ANALYSIS

Understory vegetative data are presented in three ways. 1) All vegetation data are grouped together as a comprehensive species list for the Button Rock Preserve, results include plants identified within the FHM plots and additionally encountered plants. The most abundant plants are also summarized on a project wide basis. 2) The percent cover of plants by origin (native or exotic) and cover by ground variables (rock, soil, duff, scat, wood, water, cryptobiotic soil crusts, moss) are grouped by aspect stratification (southern forests, eastern/western forests, northern forests). 3) Individual plot summaries are provided indicating the composition of each individual study plot and the origin of plants found therein.

Sampling was conducted in late April and early May. A total of 146 plants were encountered on the project site, 100 were found within the FHM sample plots ; and an additional 42 were identified on the project site as the study team traveled between field plots. There were 100 native plants, 24 exotic plants, 10 plants identified to genera, 10 unknowns and 2 naturalized plants. Eighty percent of all plants identified to species were native, 20% were exotic. A complete species list is presented in Appendix 1. The most abundant species were rated by frequency and percent cover estimations made within the 1m2 subplots of all FHM plots combined. The five most abundant plants within the project area in descending order are *Carex heliophila,* *Bromus tectorum, Clatonia rosea, Heterotheca villosa,* and *Allium cernuum.* The most abundant exotic plants within the landscape in descending order are *Bromus tectorum, Galium spurium, Agropyron intermedium, Tragopogon dubius,* and *Linaria genistifolia.* A complete list of the most abundant plants is provided in Appendix 2. These findings reflect the time of sampling and therefore contain a greater percentage of cool season plants and are not comprehensive; we recommend a warm season plant survey to create a more comprehensive species list.

The percent cover by vegetation and ground variables for each stratification are presented in Appendix 3. Southern and northern sites were 95% and 94% native respectively; eastern and western sites were only 60% native. On a project wide basis, understory species account for 17.8% of the total cover, no cryptobiotic crusts were present, moss accounted 2.2% of the total cover, and ground variables averaged

86.1%. Non-vegetative cover was comprised of duff (62.8%), bare soil (6.6%), rock (11.9%), dead wood (4.7%), and scat (0.1%).

Finally, individual plot summaries and photos are provided in Appendix 4. The composition of each individual study plot and the origin of plants found therein are summarized; plot location, basal area, stems/Ac, slope and aspect are also provided. On average, 26 species were encountered in each FHM plot.

OVERSTORY ANALYSIS

Results of the overstory analysis are presented by aspect with the same stratifications as used for the understory analysis: southern, eastern/western, and northern forests. The basal area of these areas was 27.3, 21.2, and 28.6 M^2/hectare respectively (Appendix 5). The largest trees were found on southern slopes where the DBH averaged 32.3 centimeters. Trees on eastern/western, and northern slopes were smaller averaging 20.6 and 20.3 centimeters DBH respectively. The greatest number of trees per hectare in both size classes (> 10cm DBH and < 10 cm DBH) was found on northern slopes. A total of 2250 stems per hectare were found in these areas while southern slopes had 420 stems per hectare. Species composition also varied with aspect, southern slopes were exclusively forested with ponderosa pine trees while northern slopes had a mix of ponderosa pine (51.1%), Douglas-fir (41.8%) and Rocky Mountain juniper (7.2%). Additional details of these analyses are presented in Appendix 5, figures are slope corrected and presented in both Metric and Imperial units.

The largest tree measured in a FHM plot was 58.0 cm DBH, the incidence of insect and disease infestations was low (only one occurrence of mistletoe was found). Two ponderosa pine trees likely to be greater than 200 years old were found within FHM plots; trees displaying old growth characteristics such as yellow bark, parasol top, and needle die back are common within the landscape. One western plot provided excellent documentation of the changes that have occurred to Front Range ponderosa pine forests in the absence of fire. Several trees larger than 55 centimeters DBH were found in the vicinity of Plot 7, most displayed old growth characteristics and several recorded three separate fires as basal scars. This forest has two distinct stratums, that

of old growth ponderosa with a very low basal area per acre, and that of dense, small diameter ponderosa regeneration (Figure 5). Photos of all plots are presented in Appendix 4. A description of forest insect and diseases at Button Rock, and their management is presented in Appendix 6.

The forest community at Button Rock is poised for restortation. Many mature trees are present throughout the landscape providing a critical component of historical age structure. The species composition on all aspects also resembles historical distributions: ponderosa pine trees dominate southern slopes and mix with Douglas-fir on northern slopes in a nearly equal ratio (51% pine and 41% fir). Juniper trees were slightly more prevalent on eastern and western aspects than expected (4%) and need to be thinned. These trees would have been consumed by fire historically, and can carry fire into the

FIGURE 5. The large yellow bark ponderosa pine trees each have three fire scars and display old growth characteristics. Excessive small diameter regeneration is apparent, forming a closed canopy with a basal area that is muh higher than was common historically.

canopy today. Basal area estimations indicate an overly dense forest condition. Tree densities need to be reduced from current levels to 8 to 14 M^2/Ha on southern aspects and 14 to 23 M^2/Ha on northern aspects. Most southern, eastern and western aspects present a mosaic of forests and clearings, but this pattern needs to be augmented by thinning to reduce overall density and increase the percentage of grasslands within the property. Canopy cover at Button Rock was evaluated with GIS techniques and was compared to a historical forest model made by Kaufmann et at. (Figure 2). The density categories of the historical model, and the current canopy map may not correspond with one another so it is difficult to evaluate current condition in light of the modeled forest. We do know, however, that the current landscape contains approximately 15 to 20% fewer grasslands (canopy cover 0-10%) than the historical forest did. Furthermore, there are significantly more ponderosa

pine/Douglas-fir forests (> 30% canopy closure) in the current landscape, perhaps 20% more, than was indicated in the historical model. Forest openings need to be created and a reduction in the number of stems per hectare is needed on all aspects, especially in small diameter classes. Appendix 7 presents performance standards for forestry operations.

NOXIOUS WEED ANALYSIS

Twenty-four separate weed populations were mapped during our field effort. As anticipated, most populations were adjacent to roads and trails, in riparian corridors, or were in the revegetated mining borrow pits on the western portion of the property. Species encountered included: cheatgrass (*Bromus tectorum*), toadflax (*Linaria genistifolia*), hoary cress or white top (*Cardaria draba*), curly dock (*Rumex crispus*), Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), alyssum (*Alyssum parviflorum*), diffuse knapweed (*Acosta diffusa)*, and bouncing bet (*Saporania officinalis*) [referred to as 'Phlox' in previous mapping efforts]. The riparian areas were relatively free of weeds with the exception of *C. arvense*. *Bromus tectorum* and *L. genistifolia* are widely distributed throughout the landscape; both were frequently encountered within FHM plots. Musk thistle, white top, curly doc, alyssum, pennycress, (*Thlaspi arvense*), and tall tumblemustard (*Sisymbrium altissimum*) are most abundant in the revegetated areas. Refer to Appendix 8 for a complete list of weeds encountered during sampling, their location, density, and distribution. The locations of these populations are also presented on Map 2.

Noxious species at Button Rock include cheatgrass, knapweed, Canada thistle, musk thistle, bouncing bet, white top, and toadflax. Continual weed mapping efforts are needed to track the expansion and contraction of known weed populations. Due to the timing of our sampling effort, many plants (*Carduus nutans, Acosta diffusa, and Cersium arvense)*, were in their rosette stage or may not have yet emerged from dormancy. Therefore, the actual population densities and sizes may be larger than described in our findings. Future mapping efforts should be done in July in order to more accurately gauge the severity of these infestations.

WILDLIFE ANALYSIS

Wildlife species, which might potentially inhabit the Button Rock Preserve, are listed in Appendix 10. A total of 259 bird species, 87 mammal species, 27 reptile and amphibian species, and 25 fish species were identified as possibly occurring within Button Rock. As shown in Appendix 10, the area falls within the breeding range of 178 species of birds. It also falls within the wintering range of 109 species of birds and within the migration range of 230 species of birds.

Button Rock provides potential habitat for a number of Threatened and Endangered wildlife species as shown in Appendix 10. As with more common wildlife species, the probability of occurrence within Button Rock Preserve was determined for each species after reviewing range and habitat data provided in the literature. Appendix 10 also provides a key to each species's listing status, i.e. federally and/or state listed as Threatened or Endangered and state listed as a Species of Concern. Most species listed in Appendix 10 have not been verified as occurring within Button Rock.

Wildlife species occurring at Button Rock are generally associated with habitats that include dry mountainous and rocky areas; steep terrain, cliffs and rocky outcrops; mountainous coniferous forests; cold, rocky mountain streams and lakes; and prairie-like grasslands and forest openings. Grassland are interspersed throughout coniferous forests at Button Rock. Several wetlands and riparian areas are also present providing habitat for mammal, bird, reptile and amphibian species that prefer moist areas. The two reservoirs found within Button Rock can provide habitat for waterfowl and migratory bird species such as sandpipers and other shore birds that utilize shorelines and open water during migration. Some species of raptors such as the Bald Eagle (*Haliaeetus leucocephalus*) may also be found in the vicinity of open water.

Forest thinning practices will improve habitat for some species while diminishing it for others. For example, some bird species prefer dense forests over open forests; thinning recommended will reduce the availability of these areas thereby impacting certain species. Thinning practices have pros and cons as related to wildlife habitat that should be considered prior to project implementation. To preserve critical habitat for plant and animal species at Button Rock, we recommend the following steps be integrated into the forest management plan prior to significant site alteration.

1. *Inventory* existing habitats at the Button Rock Preserve to identify any critical habitats that may exist prior to implementation forest thinning.

2. *Identify* plant and animal species that could utilize various habitats.

3. *Develop goals* to be achieved within each management unit as related to habitat preservation. This may include the preservation, expansion, and enhancement of key habitats for desirable or special status plant and animal species.

4. *Create a habitat management plan* for the Button Rock Preserve that includes a schedule for implementing habitat management practices within each management unit, estimated costs. This component should be integrated with other project objectives.

WILDFIRE ANALYSIS

Model outputs were used to focus and prioritize restoration efforts as they relate to fire hazard. Fire simulations indicated that grasslands and low density forests primarily on the northern shore of the reservoir, (south facing) were identified as priority treatment areas (Map 5). The study team incorporated findings into management prescriptions to guide "on the ground" restoration efforts. Map 5 presents the results of the model output with management compartments, fuel models are presented in Appendix 11.